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TRACKING NEXT-GENERATION AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT) INTO 2035

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Abstract

This paper explores the advances in automatic identification technology (AIT), specifically radio frequency identification (RFID), and seeks to exploit these capabilities for use in the DOD supply chain. Using technological trends, a thorough literature review, and opinions of experts, the paper compares current technology to a 2035 requirements forecast to identify capability gaps. The end goal is logistics situational awareness, where the DOD has the ability to provide end-to-end visibility throughout the DOD supply chain and can rapidly mobilize, deploy, sustain, and re-deploy forces in support of national security objectives.

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SECTION 1: INTRODUCTION

A common quote heard in military circles is "amateurs study strategy, but professionals study logistics."[1] Throughout history, wars have been won or lost depending on a nation's ability to support and sustain a fielded force. Just ask the Nazis who, during World War II, could not sustain the German war machine due to Allied destruction of logistical lines. The lessons, though similar today, are attenuated due to advances in technology, a globalized world economy, and interdependencies of nations waging war. Likewise, in a resource-constrained environment, nations and companies are "looking for ways to cut costs, improve quality, increase efficiencies and enhance their competitiveness."[2] It is no different for the Department of Defense (DOD), especially in the area of global mobility and combat support. In fact, it is safe to say that logistics situational awareness is a critical enabler to global mobility and will dictate whether nations will survive in the future strategic environment. Today, the logistics tail of the DOD is ripe for improvement. Efficiencies in the daily movement of personnel, cargo, and equipment will effect large returns on investment. Most importantly, the ability to provide end-to-end visibility throughout the DOD supply chain will permit forces to rapidly mobilize, deploy, sustain, and re-deploy in support of national security objectives.

Paper Overview

The objective of this research paper will be to survey the current automatic identification technologies (AIT) capabilities, forecast the 2035 requirements using environmental scanning and interviews, identify the capability gaps, and provide inputs for an AIT implementation roadmap. The key question will be, "How will DOD leverage AIT and help optimize the visibility of assets in the DOD supply chain for operations in 2035?" The paper will begin with a

2035 vignette to highlight the situational awareness capabilities of AIT for our nuclear assets and demonstrate the feasibility of preventing another Minot to Barksdale unauthorized transfer incident. Section 1 will provide the introduction, research questions, thesis, and paper overview. Section 2 will highlight the history and significance of AIT. Section 3 will provide the research methodology and how the research information will be used. Section 4 will review the current state of AIT with a focus on current capabilities and limitations of radio frequency identification (RFID). Section 5 will fuse the information gleaned from the literature review and expert judgments to describe future trends and provide an AIT requirements forecast for 2035. Using this forecast, Section 5 will explain what technological, environmental, and integration hurdles need to be overcome for full implementation. Finally, the results and implications of the research will be assessed in Section 6, along with a final 2035 vignette to cement the need for AIT to provide in-transit visibility for DOD's logistics system.

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On January 13, 2035 at 0115 CST, the red blip on the computer screen startled Senior Airman (SrA) Maddock as he sat at the Security Forces controller desk at Minot AFB, North Dakota. It had been a cold night with minus-15 degree temperatures and SrA Maddock was happy to be inside drinking his coffee while many of his fellow Airmen were out on base patrol. The red blip and subsequent alarm ended SrA Maddock's happy thoughts because he knew what had happened: a nuclear warhead was out of place in the munitions storage area. SrA Maddock immediately grabbed his checklist and started the phone calls in accordance with established procedures. His mind filled with possible outcomes but he focused on the task at hand. Within minutes, eight SF patrol cars surrounded the munitions storage area. A cordon was set and

communication was established between the on-scene commander, Col Buchanan, and the 5th Bomb Wing battle staff. Activity in the munitions storage area came to a halt.

Forty-five minutes earlier, TSgt James, SSgt Cook, and A1C Gilbreath had just started their mid-shift work. They received the normal mid-shift brief from MSgt Gray and were given the task of building the munitions for the next day's B-52 flying schedule. The Air-Launched Cruise Missile (ALCM) load was an important certification for the munitions personnel, weapons load personnel, and aircrew for the next day's mission to Barksdale AFB. Strict procedures were in place and the two-man rule was the norm for these die-hard Ammo troops within the munitions storage area. The week before, the 5th Bomb Wing had undergone a Limited Nuclear Surety Inspection and passed with a "Satisfactory" rating. Unfortunately, in the rush to return to normalcy after the inspection, a nuclear-tipped ALCM was accidently placed in the wrong storage case, the one marked "Inert – Captive Flight Only." As SSgt Cook and A1C Gilbreath opened the case, they followed the technical data, but had no idea that they had a live nuclear warhead. While the nuclear ALCM was loaded on the munitions trailer, the three-man team continued to assemble the other seven ALCMs. As the end of shift neared, all eight ALCMs were loaded on the munitions trailers and the slow transport was started to the weapons load facility where the ALCMs would be carefully populated on an empty rotary launcher. As SSgt Cook drove the bobtail through Gate 4 in the storage area, the alarms sounded. Everyone stopped dead in their tracks.

With the help of RFID readers mounted on each munitions igloo and vehicle, Munitions Control was able to identify the location and status of all the munitions personnel, vehicles, equipment, tools, and munitions on base at the touch of a button.

According to established procedures, Col Buchanan sent security forces personnel and the 5th Munitions Squadron Munitions Accountable Systems Officer into the munitions storage area with a handheld sensor to verify each person, his or her qualifications, and security clearance contained on the badges each person wore. Everyone checked good. Next, the munitions trailer with the nuclear warhead was discovered at Gate 4. Using the handheld sensors, the nuclear warhead was promptly located, removed, and properly stored in the correct container. The nuclear warhead had an RFID tag which alerted security personnel that it was out of place. The positive inventory control system enabled by RFID started the chain of events and averted another Minot-Barksdale nuclear weapons transfer incident.

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Preventing another Minot-Barksdale nuclear transfer is instrumental in safekeeping nuclear material and being stewards of the nation's nuclear arsenal. RFID can help automate and safeguard these critical capabilities. In addition, current RFID technology is available to make munitions inventorying, location identification, and environmental monitoring possible.

Research Questions and Thesis

How should the DOD navigate the advances of technologies and exploit the capabilities of logistics situational awareness in the coming decades? In particular, what technologies are needed to identify, track, trace, and help optimize the visibility of assets in the DOD supply chain to fight the nation's wars in 2035?

DOD investments in AIT will promote efficient logistics operations, streamline supply chains, provide in-transit visibility, and enhance situational awareness to enable rapid global mobility, agile combat support, and power projection for the DOD in 2035.

SECTION 2: BACKGROUND

AIT is a tool set of technologies "enabling the automatic capture of data, thereby enhancing the ability to identify, track, document, and control assets."[3] A variety of data storage and transfer technologies encompass AIT to include "bar codes, magnetic strips, integrated circuit cards, optical laser discs, satellite tracking, and radio frequency identification (RFID) tags."[4] To narrow the scope of research, this paper will primarily focus on RFID technologies, applications, future trends, and implications. It is important to note that "AIT is not a system or a single product," but a family of technologies.[5] When AIT is integrated with information systems, it becomes a powerful logistical tool. This situational awareness, or asset visibility, is the "capability to provide timely and accurate information on the location, movement, status and identity of units, personnel, equipment, and supplies."[6] The DOD has invested over 30 years of research into AIT, starting with the bar code and progressing now to advanced technologies, and considers AIT a key enabler to daily operations.[7] However, the DOD relies heavily on current commercial investment and applications of AIT, more precisely RFID, which had beginnings much earlier.

History of AIT and RFID

During the 1800s, inventors such as Faraday, Maxwell, and Hertz published theories on light and radio waves, which laid the foundation for understanding electromagnetic energy.[8] The

1900s showed progress, with the birth of radar in 1922 and the early development of "identification, friend or foe (IFF) for aircraft" in the 1950s.[9] During Vietnam, the Igloo White system used RFID and other networked sensors to track enemy movements on the Ho Chi Minh Trail.[10] While early DOD applications drove much of the initial research, commercial applications accelerated. In the 1970's, the retail supply chain pursued barcodes as the primary technology for auto identification.[11] The 1990s saw technology developments in RFID for transportation and "wide scale deployment of electronic toll collection in the United States."[12] More recently, RFID tracks positions of assets, identifies personnel and vehicles, and can sense an enemy sniper's location using acoustic sensors coupled with RFID.[13] However, it was not until mid-2008 that RFID applications led to a breakthrough in industry. Experts attribute this to two things: 1) passive tag technology in UHF stabilized, and 2) the apparel distributor, Dillard's, started to place passive RFID tags on items of apparel in the retail supply chain.[14] Today, applications are prolific and RFID operates in "industrial manufacturing sites, in warehouses, at ocean and aerial ports, in retail stores, at ammunition storage and manufacturing sites, at transportation distribution facilities, and in austere environments."[15] Appendix C provides a more complete list of current RFID applications.

At the basic level, "RFID is a generic technology that refers to the use of radio frequency waves to identify objects."[16] RFID is "an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders."[17] These tags can be attached to or incorporated on just about any object for identification and usually consist of two parts: an integrated circuit for storing information, processing information, and modulating radio frequency signals, and "an antenna for receiving and transmitting the signal."[18] RFID tags can be either active or passive. Active tags are powered by batteries and have one- or two-way radio

transceivers, data storage memory, and a read range of up to 300 feet.[19] Passive tags are powered by the current induced from a radio frequency signal, have short read ranges of up to 15 feet, and have the advantages of reduced size, less upkeep, and greater cost effectiveness, which makes them prime candidates for nanotechnology miniaturization.[20] Technologists agree that batch fabrication of passive RFID tags with mini-circuits and antennas would drive the unit price down and increase reliability.[21] As this technology continues to miniaturize, it is even possible to embed tags on smaller objects, like metal bolts or washers.

The active or passive tags also rely on interrogators, fixed or portable handheld devices that "emit electronic signals to communicate with the tags."[22] The interrogators, or readers, are usually fixed on poles, loading docks, or doorways to allow for accessible read ranges in proximity to the tagged items. Additionally, a computer connected to a network helps control the interrogator, capture the necessary data, and send the data in the established technical architecture. Finally, the data read by RFID technology provides valuable information to decision-makers. Software and information technology architectures help channel and mine the data for trends and decision tools; however, how the data is used becomes even more important than getting the data.

The tags, interrogators, computers, and data make up the main components of an RFID system. The system of interrogators and active tags work in conjunction with networked information systems to provide visibility. As a networked tag is placed on an item, the user now has the ability to inventory, determine where an object is located, and where the object has been, and can remove outdated objects, eliminate stock-outs, and provide in-transit visibility on a global network.[23]

Significance of RFID

While the history and basic functions of RFID are interesting, what is the current significance of RFID? According to the analyst firm IDTechEx, RFID is big business with a global market of $5.29 billion (2008).[24] This is only predicted to grow, with some forecasting "a 15 percent annual growth rate over the next five years."[25] Many experts place the jump-start of RFID applications to Wal-Mart's mandate in June 2003 to place RFID tags on pallets and cases from their top 100 suppliers.[26,27] Albertson's, Target, Proctor & Gamble, and the DOD followed with pursuits to improve the supply chain and reduce costs.[28] Overall, every organization agrees that the pursuit of "information visibility (and the corresponding timeliness of information) is critical to supply chain operations."[29] With RFID serving as a "business process enabler," these organizations are reaping the benefits of increased visibility.[30] As one Wal-Mart Chief Information Officer said, "I view RFID as a strategy that offers tremendous competitive advantage."[31]

What is RFID's significance for the DOD? Consider the recent decision by President Barack Obama to send 30,000 more troops to Afghanistan.[32] The United States Transportation Command (TRANSCOM) is charged with the daunting task of moving and distributing all the troops and equipment. One Army Brigade Combat Team (BCT) has approximately 3,500 personnel, 1,200 short tons of airlift cargo, and 200,000 sq. ft. of sealift cargo that requires 80 C-17 airlift missions and two ships.[33] Multiply this by ten and then consider the transportation modes to Afghanistan where 50 percent of the cargo goes by truck, 30 percent by rail, and 20 percent by airlift.[34] Imagine you are a commander in charge of deploying a BCT and all of your personnel and equipment must end up at your deployed location on a certain date. RFID, along with other AIT, will provide an efficient way to manage the personnel and cargo strewn out

across the globe. RFID technologies will be crucial to provide asset visibility and in-transit visibility for the passengers and equipment moving from origin to destination by commercial airlift, sealift, and surface assets.

SECTION 3: FUTURES RESEARCH METHODOLOGY

The objective of this paper was not to predict the future, but to highlight key AIT trends in order to enable better decision-making and address future opportunities or threats. With this in mind, the research methodology for this paper was environmental scanning, a thorough database literature review, and interviews with experts. This approach helped build a foundation to assess current and future trends in AIT and build a 2035 AIT requirements forecast for the year 2035.

Environmental Scanning

Considerable information and literature are available in the field of AIT, which spans the U.S. Government, commercial industry, and academia. A review of literature beginning in 2000 through 2010 revealed significant trends that warranted further investigation. Database literature reviews of international journals and technical papers were primarily utilized to identify developments and assumptions about the future. In addition, these literature sources provided a broad view of the current state of RFID and AIT technologies. Prominent and helpful information was gleaned from publications such as *Proceedings of the IEEE,* the Rand Corporation, *Industry Week*, *Production and Operations Management*, *Industrial Engineer*, *Communications of the ACM*, and *RFID Journal*. The internet also proved useful to data-mine government, industry, and academic websites for background support. Information obtained

from these sources was categorized into "current state" or "future state" bins to help ease the filtering of data. Current capabilities, trends, and developments found in the literature review are discussed in Sections 4 and 5.

Expert Interviews

As a corollary to the literature review, interviews with leading experts in the field of AIT were conducted. While much of these experts' findings are contained in conference minutes, published papers, and academic or government websites, conducting email or phone interviews with these individuals proved very useful. Initial plans were to contact experts from the United States Transportation Command (USTRANSCOM), Defense Logistics Agency (DLA), AF AIT Program Office, AF Logistics Management Agency (AFLMA), Army AIT Program Office, Center for Army Lessons Learned (CALL), the University of Arkansas, Federal Express, Transcore Inc., and Walmart. These experts spanned the spectrum of government, industry, and academia, which brought focus, relevance, and application to the research. See Appendix A for contact information. The goal was to ask the experts targeted questions related to AIT trends and to explore recommendations on policy and strategy. The first round of questions focused on experts in industry and academia to gain insight on current trends, limitations, future trends, and recommended strategies for AIT. Next, questions were formulated to interview the DOD experts on future military capabilities, AIT applications, investment opportunities, and recommended DOD policies. See Appendix B for the specific questions posed. These observations and judgments about future developments were combined with information in the literature review to build an AIT requirements forecast for 2035.

SECTION 4: CURRENT STATE OF RFID

As mentioned earlier, the main reason organizations pursue RFID is to enhance information visibility. In fact, experts in supply chain management suggest that "the success of a supply chain system depends on the level (and timeliness) of visibility it has on the materials from suppliers to customers."[35] With visibility as the overarching goal, industry and government organizations have taken RFID technology, translated it into process efficiencies, and reduced costs. According to USTRANSCOM, the DOD's primary use of AIT is "to facilitate data management" by improving data accuracy, reducing data capture and processing time, reducing data latency, and enhancing supply chain management monitoring.[36]

Current RFID Capabilities

In order to summarize the information found during environmental scanning, this section will highlight some broad categories of AIT capability and provide current examples from government or industry. The following overarching AIT capabilities are discussed:

- Automation
- Asset Management
- Inventory Management
- People Management
- Layering AIT
- Standards

1. Automation

As industry and government seek ways to make processes more efficient and reduce costs, automation has been a key focus, especially in processes where humans conduct repetitious action. RFID helps eliminate manual entry, parse data, and is "not constrained by line of sight," which allows tags to be a distance away as long as they are within the reader's signal range.[37] Unlike barcodes, many RFID tags can be read simultaneously which allows batch processing versus one-piece flow.[38] Another characteristic of RFID is the ability to operate in harsh environments where human access is prohibitive or less cost effective. Tags are "resistant to heat, dirt, and solvents and hence are not physically damaged easily."[39] One perfect example of automation is electronic toll collection. The 1991 opening of the first electronic toll booth in Oklahoma represented an RFID automation of a prior manual process.[40,41] Passive tags on cars pass through the readers (interrogators) located in the tollbooth. As the cars pass, the RF signal sent from the readers attenuate the passive tags on the cars. The interrogators read the attenuated return signal from each passive tag. Finally, the computer system links the unique passive tag on the car to a user account to which the toll is debited. Based on this example and others, it is clear RFID allows organizations to save time and labor by exploiting the technology's automation features.

2. Asset Management

On the surface, it is logical to have the ability to know where an asset is located; however, this is just one aspect of asset management. RFID also allows organizations to track and trace assets across an enterprise system. It answers the question, "Where is my asset?" The ability to identify, locate, sense the condition of an asset, and automate timing or sequence in a timely manner provides great efficiency to any process. For example, after the Taiwan nuclear

shipping incident of 2008, the Nuclear Weapon Center at Hill AFB opened a new facility to manage nuclear-related material.[42] This facility uses the Positive Inventory Control System (PICS) to track nuclear-related assets in storage, transit, or maintenance activities.[43] Using passive RFID tags, unique item identification (UID), handheld readers, portal interrogators, and an enterprise data system, PICS manages the delivery, receipt, and verification of critical nuclear assets at any point in the lifecycle.[44] Additionally, Airbus has implemented RFID to help manage assets at the A380 final assembly plant in Hamburg, Germany.[45] It takes 750 containers of parts to assemble an A380 and the bulky containers are delivered across a four-story assembly plant.[46] The asset management system tracks over 3,000 containers from suppliers and makes sure they are delivered to a specific assembly location "on time, the right time, the first time."[47] Airbus has saved time, money, and space in addition to knowing timing, sequencing, and visibility of their containers.

3. Inventory Management

Another capability of RFID is inventory management. This answers the question, "How much do I have?" Whether it is government, retail industry, or healthcare, the ability to have an accurate, real-time inventory is a critical process enabler and often improves safety. Take, for instance, the application for RFID to help in air-to-air refueling between KC-135 tankers and other aircraft. In April 2010, the AF plans to demonstrate the capability to read specialized passive RFID tags on aircraft being refueled, which identifies the type of aircraft, time, location, and amount of fuel passed.[48] The biggest benefit is the accuracy of the fuel inventory. Before, boom operators could not read tail numbers or miscalculated fuel passed, which accounted for millions of dollars of unpaid bills for fuel costs. Now, all the fuel is accounted for, aircraft

information is automatically recorded, and the boom operator can focus on safely refueling without having to record information.[49] Likewise, the retail giant, Wal-Mart, has found that RFID improves the efficiency and effectiveness of their processes. One study revealed they reduced out of stocks by 26 percent, reduced the number of receiving errors, improved the accuracy of inventory, and ultimately were able to better forecast and replenish items for customers.[50] This has great relevance to the DOD distribution centers where assets are received, inventoried, stored, and shipped to customers worldwide.

4. People Management

Another useful capability of AIT has been people management. This concerns embedded chips in humans (similar to RFID chips in animals), but these capabilities are wrought with legal and privacy concerns. More common applications are identity cards, passports, or magnetic credit cards that provide identity verification, control access to buildings, or limit use of equipment. A perfect example is the common access card (CAC) issued to DOD employees for access to computer networks and positive identification. The RFID tag in the card contains personnel information, but is also capable of holding medical information, training qualifications, and other pertinent data. While cards are common, people management is most prominent in the healthcare sector. Not only do hospitals "track and manage medical devices, wheelchairs, and surgical equipment," but they also monitor patients.[51] A US healthcare provider has introduced infant ID tags that alert hospital staff when a tag is tampered with or lock doors when the ID tag is approaching an exit.[52] In addition, some medications are tagged to ensure the right patient receives the right dose at the right time.[53] Whether it is drug dosage,

laboratory samples, or patient wristbands, healthcare providers are seeing solid improvements in safety, cost, and process efficiency using AIT.

5. Layering AIT

AIT is a family of technologies with RFID being one form of media. Due to the economic realities of business, a layering of technologies has proven feasible. The sunk cost of legacy systems combined with the redundancy of technologies helps mitigate risk and provides flexibility in infrastructure planning. As the promises of passive RFID gained ground in the late 1990s, the barcode gave way to the electronic product code (EPC). In essence, the EPC is an electronic bar code that uniquely identifies an object, even differentiating between like objects due to an extra set of numbers.[54] In line with EPCs came the DOD's mandate for item unique identification (IUID) in a policy memo in 2003. The purpose of IUID was to "distinguish one item from another," even same part numbers, so the DOD could "achieve total asset visibility, improved item management, and clean financial audits for DOD property."[55] The UID and EPC combination made an item globally unique, enabling it to be tracked in "operation, maintenance, storage, and finally disposal."[56] UID 2-D markings, EPC labels, integrated sensors, and the barcode are perfect examples of other technologies commonly put on products in addition to RFID tags. In fact, the DOD has mandated that the "linear bar codes will remain as a recommended backup baseline AIT" for all items.[57]

As material flows through the supply system, it becomes apparent that items are very different in physical size and may require unique conveyance. Packaging for distribution is a science in itself; however, standardized practices are followed. Figure 1 helps to illustrate the standardized consolidation layers the DOD employs. Different AIT media are used at each layer

and one can that shipments can become complex when the stakeholders in the process may have different infrastructure or capabilities to support the AIT media. One current example is the shipment of Mine-Resistant Ambush Protected (MRAP) vehicles to Afghanistan. Due to the MRAP size and value, active RFID tags are strapped to the vehicle's bumper. As the ship or aircraft convey the vehicle, the active tags work in concert with GPS satellites and interrogators at all ports to track the shipment until the final destination. The layering of active tags, interrogators, and satellite networks provides the in-transit visibility for the MRAP shipment.

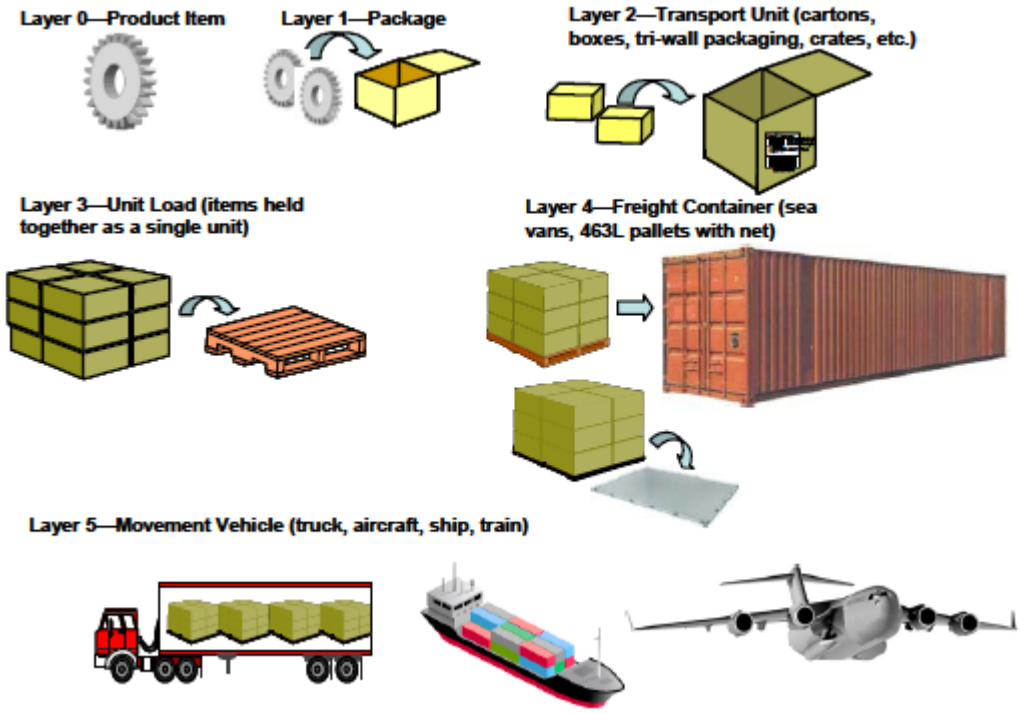

Figure 1: Consolidation Layering
(Source: United States Transportation Command. DoD Automatic Identification Technology Concept of Operations for Supply and Distribution Operations, 11 June 2007, 3-10.)

6. Standards

While some proponents consider RFID standards to be a limitation and challenge, further research revealed copious policies and standards for RFID in the government, international, and

industry sectors. Before 2000, many articles highlighted concerns over standardization mainly by privacy activists; however, the startup of EPCglobal and Wal-Mart's decision in 2003 helped cement robust standards still in place today. RFID follows a number of standards, including the International Organization for Standardization (ISO), International Electro-technical Commission (IEC), EPCglobal, and European Telecommunications Standard Institute (ETSI).[58] Additionally, standard frequency ranges for RFID include low frequency (LF), high frequency (HF), ultra high frequency (UHF), and microwave frequency, with RFID readers supporting UHF and microwave frequencies in recent years.[59]

For the DOD, USTRANSCOM is the lead agent responsible for RFID and AIT standards, security, and technical matters. Additionally, USTRANSCOM participates in DOD, commercial, national, and international standards committees and forums.[60] In the DOD, "application of the various AIT technologies shall be based to the maximum extent practicable on consensus based commercial standards" as dictated by Public Law.[61] In other words, the DOD follows commercial investments in standards to cut costs and facilitate interoperability with commercial systems.[62]

Current Limitations and Shortfalls

The environmental scanning also highlighted some limitations and shortfalls of current AIT capabilities. The experts interviewed also confirmed that these are indeed areas requiring thought, further research, or investment. Similar to the current capabilities section, this section will summarize some broad categories of limitations or shortfalls and propose questions that need further exploration. The following limitations will be discussed:

- Expectation versus Reality

- Form Factor
- Readers or Interrogators
- Data Management and Security
- Interoperability
- Cost

1. Expectations versus Reality

The single biggest limitation of RFID is not with the technology itself, but with the expectations of it. The hype over Wal-Mart's 2003 implementation has given way to disillusionment over how to use RFID technology and the data it provides. In fact, experts currently place RFID in the "trough of disillusionment" or "slightly up the slope of enlightenment" on the Hype Cycle.[63,64]

First, government and industry approach RFID as a barcode replacement system or consider it better than the barcode.[65,66] However, the barcode has many advantages in comparison to RFID, including line of sight operations, no power source, one read at a time, less expense, use around water and metal, and pre-printed capabilities.[67] The myth is that every process will benefit from RFID, when, in fact, the barcode or some other method could be better. An expert even offered that "80 percent of a process must use some type of AIT media to make the investment even worthwhile."[68] Unless the technology enables the process, the process details and not necessarily the technology are critical.

The next expectation is that item-level visibility is better than pallet-level visibility. Some say the "slap and ship" approach to individual items enhances the process, while others say the pallet-level tags limit visibility in the supply chain. Given an apples-to-apples comparison,

maybe so, but consider this example. Federal Express, one of the world's logistical leaders, does not use RFID tagging because it slows them down.[69] The time it takes to put a tag on a package and read the package on high-speed conveyors only sub-optimizes their process. The lesson for the DOD is that not every process may benefit from RFID applications.

2. Form Factor

Form factor refers to the technology's size, packaging, durability, data capacity, and attaching or affixing methods.[70] Currently both active and passive tags must get smaller, since many processes demand that small items be tagged to provide the item-level visibility needed. However, how small is too small? As with any technology system, it comes down to tradeoffs. Antenna technology is limited by physics, circuit technology by manufacturing, and data capacity by size; and packaging may dictate orienting a tag on top of the item. These factors will affect tag size. Additionally, tag power is a critical feature affecting size and performance. Passive tags have no battery, but "the life of an active tag is directly related to battery life."[71] Therefore, durability comes into play when choosing whether to include a battery. Another performance tradeoff is the attaching or affixing method. Will this be a reusable tag? Will the tag be imbedded in the item? Will layering of AIT still be required? Will the tag be durable enough to withstand harsh conditions? Can the tag be attached to cardboard, wood, plastic, or metal?[72] These are all complex questions that limit RFID tag capabilities.

3. Readers or Interrogators

Not only are the RFID tags affected, but readers and interrogators have similar limitations. Primarily, the read range of current interrogators is constrained. Barcodes require

line of sight, passive tags read at 10 to 20 feet, and active tags read from 300 feet.[73] Read ranges in turn affect mobility and quantities of the reader infrastructure as well. This performance severely limits the footprint and layout of distribution centers or portals. While handheld readers provide some mobility, other characteristics such as size, ergonomics, power, and connectivity to back-end databases also affect the performance.

Another common complaint from RFID readers is the less than perfect read rates. Not all tags that pass within range of the interrogators are read. It is well-documented that RF signals do not perform well around liquids and metals.[74] Attenuation and RF interference play a significant role in degrading the reader performance. Additionally, signal frequency, signal power, packaging, and physical obstructions also affect the read rates. In fact, one recent study of palletized consumer products found that readability was most dependent on the forklift speed through the reader portals.[75] Overall, RFID readability rates have not been able to reach full potential due to several complex technical limitations.

4. Data Management and Security

When industry and government organizations implement RFID, a common question is, "How do I use the data captured?" Data management becomes a big hurdle to understand, manipulate, and consolidate; however, the data must be usable in order to make better decisions. In many cases, filtering data may be necessary due to missing reads, multiple reads, layout problems, or hardware malfunctions.[76] Also, the decision software, network capacity, and network architecture need "to handle vast quantities of data generated by RFID."[77] Upfront planning is needed to manage this volume of data flow.

Data security is another contentious RFID issue. Sparked mainly by consumer privacy advocates, the fear is that proliferation of RFID tags on consumer products will threaten civil liberties.[78] For business applications, corporate espionage is a sizable risk due to the unsecure wireless data sent between the tag and reader.[79] Currently, commercial EPC tags "do not offer access controls for reading the EPC, only for write-protecting data on the tag."[80] This is an information assurance risk for the DOD as well, since many active tags store data and are susceptible to adversary intelligence collection. Overall, the shortfalls in data security could hurt competitive advantage in business sectors and put personnel or equipment at risk in future DOD ventures.

5. Interoperability

With the many commercial, national, and international standards in place for RFID, operating global supply systems has become a challenge. Interoperability between RFID hardware and various IT systems requires robust middleware that is not yet mature.[81] Many organizations operate enterprise resource systems that compile and store all the back-end data, but this data migration is costly. To complicate matters, implementation with legacy systems in any organization is also IT intensive. Additionally, most RFID devices work in certain frequency ranges (for example, UHF for most supply chain applications), but international infrastructure may operate on different frequency bands. As a result, organizations (the DOD especially) may be limited in having visibility in certain locations due to incompatibilities. These risks require strong mitigation plans and in-house experts to consider viable alternatives.

6. Cost

There is no doubt that cost is a prohibitive factor for many organizations seeking to implement RFID systems. Infrastructure alone is the largest bill (readers, software, computers, and data storage), but the unit cost can be sizable, too. Current barcodes cost pennies compared to passive tags costing 20 cents to $5 and active tags costing $70 to $100, depending on capability.[82] And the key question is, "What capabilities does the organization need?" One recent study found that AF base-level supply should remain with current barcode technology due to the investment cost benefit and reduced risk.[83] In particular, barcode technology was a fielded technology, had less risk for read errors, had user confidence, and was capable of handling the process volume.[84] Interestingly, volume was the most significant variable in the base supply and distribution process examined in the study.[85] Additionally, a GAO report in 2006 highlighted that the "DOD's current RFID policy does not require active tags to be returned or reused even though these tags are designed for repeated reuse."[86] With over 1.1 million active tags by 2006 and an average unit price of $100, the report urged more efficient management of active tags and mandatory reuse to potentially save millions of dollars in active tag purchases.[87] As one can see, economic benefits drive many RFID implementation decisions and keep some potential users out of the market until costs decrease.

SECTION 5: FUTURE STATE OF RFID

As Dwight D. Eisenhower once said, "In preparing for battle I have always found that plans are useless, but planning is indispensable." While many people discount the accuracy of forecasting and futures research, the real value is in the process of future forecasting. Future forecasting is not black magic, but understanding the strategic environment and trends, and applying the rigor of common sense.

Future Trends

In assessing future trends, it is important to keep in mind that the DOD logistics system needs to maintain a strategic advantage in order to win the nation's wars. In order to maintain a strategic advantage, it is important to understand the future strategic operating environment. To characterize this operating environment, the following future trend categories were assessed to be most relevant to AIT using available literature and expert judgments.

- Political, Social, Economic Environment
- Future Warfare
- Computing
- Power
- Sensors
- Wireless Networks

1. Political, Social, Economic Environment

While the US is still expected to be a dominant power, international influence will narrow between developed and undeveloped countries in 2025 with non-state actors increasing in strength.[88] Economic growth is expected to boom in Brazil, Russia, India, and China (BRIC) over the next 20 years with the shift of "manufacturing and service industries to Asia."[89] As the global population increases, the "demand for food will rise by 50 percent by 2030"[90] and "energy scarcity will drive countries to take actions to assure their future access to energy supplies."[91] This will increase threats to US interests and strain energy resources, economic, and diplomatic relations with global partners. While the US will continue to grow economically, limited

resources will force companies to push efficiency, process improvement, reduce labor costs, and seek automation. The trend toward complexity will continue where no major global event is isolated and everything is intertwined in a globalized economy.

2. Future Warfare

What will warfare be like in the next 25 years? Irregular warfare will be the continuous fight, but the US must be able to fight the major conventional operation with a near-peer adversary. As the military intervenes in humanitarian assistance, peacekeeping, stability and reconstruction, or counter-insurgency operations, the ability to mobilize forces and project power around the globe will be critical. The US will continue to fight wars with similar historical approaches: casualty sensitive, technology oriented, expanded battlefields (to control the tempo, size, and depth), and the desire for a short duration conflict.[92] The demands for accuracy, speed, and versatility in future warfare dictate close coordination and interoperability with US government agencies, commercial industry, coalition partners, and non-governmental organizations.[93] Non-linear operations in a highly networked battle space will be the norm as simultaneous movement along multiple lines of operation will be required. Sustaining trained and equipped forces will also be complex as there may be limited access to sea or aerial ports in contested environments or difficult terrain.

3. Computing

One particularly noteworthy trend in the literature review was the advances in micro- and nanotechnologies. Many futurists, strategists, and policy makers predict large commercial investment in this area with promising benefits of increased information throughput, reduced

size, reduced weight, and robust materials that will enable AIT. With this form factor reduction, mobile-communication devices will have an ever-increasing computing power. In fact, "digital electronics with increased density (~ 128X) is projected by the integrated circuit industry over the next 15 years."[94] As the integrated circuit density increases, trends toward new structures (dual-gate and depleted, silicon-on-insulator integrated circuits), effective power management, and increased computational power will continue.[95]

Data memory has also benefited from micro- and nanotechnologies with a "62.5-fold increase in data-storage capacity" since 1998.[96] Active research in carbon nanotube-enabled memory, phase-change memory, magneto-resistive random-access memory, and ferro-electric random-access memory has shown potential to provide larger capacity, reduce manufacturing costs, maintain non-volatility, and reduce power consumption.[97]

4. Power

According to Rand, "batteries and power-storage devices…have the greatest potential to influence future growth of mobile-computing devices."[98] The advances in nano-structured, material research continue to fuel the potential for these devices as they seek "to increase the capability and computational power…while minimizing the power they consume."[99] Thin-film batteries hold great promise over conventional batteries due to the composition of solid-state materials, wide operating temperatures, longer shelf life, producible form factors, and fixed cost per area.[100] These thin-film batteries are ideally suited for "embedded power on printed circuit boards…, smart cards, and smaller active-RFID tags."[101] Additionally, research with carbon nanotubes has shown that electrodes with more surface area have a greater charge capacity.[102] This makes ultracapacitors a possible choice for mobile devices due to their resistance to shock

and temperature.[103] Other energy harvesting technologies to harness the energy of sunlight or mechanical vibration is mature; however, there is still a need to store the harvested energy.[104]

5. Sensors

Integrating advanced monitoring and sensing devices has also been an emerging AIT capability. Specifically, wireless sensor nodes ("motes") and micro-electromechanical systems (MEMS) show great promise "to revolutionize low-cost, low-power sensing."[105] The goal is "to enable networked surveillance" by "improving the security and efficiency of supply chains."[106] These sensors provide the ability to detect movement, acceleration, pressure, biological substances, chemicals, fluid flow, and audio.[107,108] For the DOD, the interest lies in monitoring "condition and health indicators of operating systems to warn of conditions such as equipment failures, needed maintenance, or breaches to security."[109] So, "fundamental changes in sensing architectures" will be needed for integration of "multi-spectral, multifunctional sensors."[110]

6. Wireless Networks

The growth of mobile devices has skyrocketing in the past few years with the help of cell phone technology. Some futurists predict that by "giving so many more people the tools and ability to connect, compete, and collaborate," the technology will act as an "equalizing power" for societies.[111] Technological progress depends on open communication, collaboration, and easy access or exchange of information. This trend will drive systemic and integrated hardware for communication networks linked by software.

Another key trend was the need and technical feasibility for longer-range wireless networks and ubiquitous computing for intelligent autonomous operations. In fact, a 2006 Rand

study ranked RFID tagging and ubiquitous information access in the "top 16" technology trend areas for 2020 with a strong market need and high technical feasibility.[112] As RFID tags gain the capability to double as readers, a "mesh network" is formed with the ability to sense the surrounding environment. These connected nodes provide a continuous, redundant, and reliable network, which can operate even when a node or connection breaks.[113] As wireless networks expand, software will be required to control a mobile device's range, power consumption, and data rate, in addition to operating and communicating using multiple frequencies and protocols.[114] Interoperability will be crucial as AIT operate in a multi-sensory environment consisting of passive tags, active tags, UHF, LF, ultra wide band, Wi-Fi, and a "low-power wireless technology called Zibee."[115,116]

Requirements Forecast for 2035

Bernard Baruch once said, "If all you have is a hammer, everything looks like a nail." The initial inclination is to look at future requirements through the lens of today's technology. While helpful initially, this approach blinds the mind to many possibilities and future courses of action. While recognizing RFID is not the only AIT, this forecast in a way has limited the courses of action by focusing on RFID. However, the observations and judgments gleaned from the literature review and expert interviews found RFID to be the most promising and widely flexible technology within the AIT technology family. The intent was to prevent portraying RFID as a "plug-n-play" or "one-size-fits-all technology" for the future, but focus on its inherent capabilities.

Fusing the observations and judgments gleaned from the literature review and expert interviews proved a difficult task as an AIT requirements forecast for 2035 was built. As stated

in the introduction, the purpose of this paper was to help the DOD navigate the advances of technologies and exploit the capabilities of logistics situational awareness to win the nation's wars in the coming decades. The AIT requirements for 2035 are as follows:

- Identify: The ability to uniquely identify an item with a part number, serial number, manufacturing information, value, and maintenance history (similar to UID or EPC).[117] The ability to move a single item through a supply chain and distinguish it from other items, even if part of a consolidated shipment.
- Locate: The ability to dynamically update precise position information of any asset, in any location. This is especially important for "critical items that are in short supply."[118]
- Condition Monitoring: The ability to monitor an asset "in the supply chain to detect a specific condition that would be adverse to the serviceability, functionality, safety, or security of the item."[119]

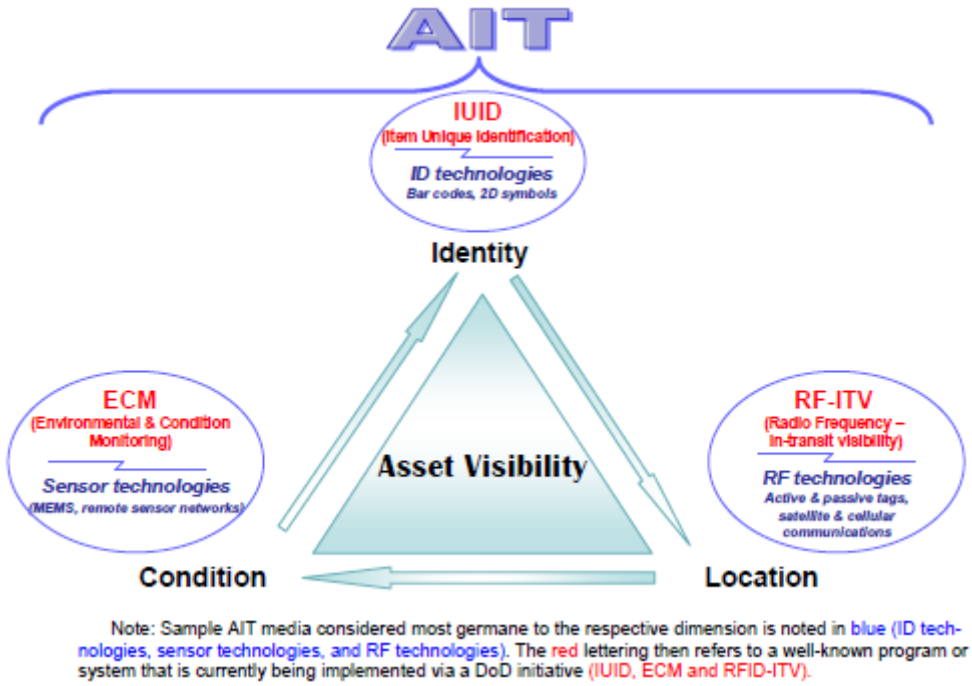

Figure 2: Three Dimensions of Asset Visibility

(Source: United States Transportation Command. DoD Automatic Identification Technology Concept of Operations for Supply and Distribution Operations, 11 June 2007, 4-11.)

- Connectivity: The necessity for flexibility in connecting to wired, wireless, mesh, or ad-hoc networks continually to enable synchronized, reliable data delivery.
- Interoperable Architectures: The AIT media, readers, and IT infrastructure must be able to operate on multiple networks and frequencies in austere locations. This architectural framework must be capable of managing a sensor-based logistics system with Coalition, commercial, and government agencies. This includes command and control data architecture interoperable with commercial or Coalition standards and physical architectures that are mobile and deployable.
- Software: The architectural framework demands user-friendly software that seamlessly links legacy systems and a sensor-based system. The goal of the software would be to enhance visibility across an enterprise, which necessitates collecting, integrating, storing, and analyzing data to enable better decisions.[120]
- Dynamic Routing: The ability to track, decide, and redirect shipments real-time using a combination of AIT. Using the information of a networked battle space, the DOD must move and track assets with accuracy and enough flexibility to adapt to the fog and friction of war.
- Security: The ability to move assets and pass information without threat of loss, theft, interference, or monitoring. Security requirements include "access control, data encryption, message authentication, key exchange, and certification of trust."[121]
- Reliability and Survivability: Reliable read rates from maintenance-free devices that withstand harsh operating conditions and survive those operating conditions throughout

the life cycle. Devices that quickly transition from powered state to unpowered state or power harvest to minimize power consumption.[122]

RFID Challenges for 2035

General George C. Casey once said, "Somewhere on the far end of the supply and distribution chain is a customer who needs something…amplified by distance and time. Our job is to respond and deliver."[123] So what are the capability gaps and risks in delivering these AIT capabilities for the future? Using the 2035 requirements forecast as a future state, the following challenges and hurdles need to be overcome for full implementation of the 2035 vision.

- Implementation Challenges: The focus should be on processes and not just implementing AIT across the board. There is a risk of sub-optimizing a process by using AIT to enable efficiencies in one area, but creating bottlenecks in the overall process.[124] AIT should be a process enabler "linked to a valid business approach."[125] In a resource constrained environment, the high infrastructure cost of AIT must demonstrate an investment return.
- Operating Environment: The DOD must possess the ability to provide global logistics support for widely dispersed operations while retaining the ability to determine the time, tempo, and terms of the conflict or operation.
- Expeditionary Capability: Likely deployment locations will not have the IT infrastructure to support RFID. Deployable infrastructure and mobile readers are needed to establish mobile port opening capability packages with the necessary command and control functions.
- Transportation Infrastructure Dependencies: The DOD must manage the complex interaction between capacity, demand, and reliability to assure on-time delivery. The

transportation system must adapt to constraints in various ways to include shifting modes, shifting demands in time and space, moving manufacture points, choosing alternative points of entry, and changing prices.[126] The reliance on commercial transportation networks and international ports increases the risk of timely access to the global lines of communication.

- Information Assurance: If AIT sensors are all over the world gathering and transmitting information, the concern is over customer profiling, manipulation of data by adversaries, and theft of intellectual property. In addition, the reliance on information technology creates increasing DOD vulnerabilities, which produce asymmetric avenues of approach for adversaries that must be secured. Capturing, security of, and access to the data are the main concerns. In some cases, keeping data on an active tag is necessary. In other cases, data could be stored in a secure database and referenced with a license plate scan. Data encryption will not be enough if interoperability is a key performance attribute. Some may say, "To have more security we have to give up some privacy."[127] AIT benefits are great in a networked environment; however, experts suggest a cautious approach to ensure data security and privacy violations are open for public debate.
- Data Capture: In a multi-sensory environment, bandwidth and frequency spectrum deconfliction will be paramount. Multipath propagation effects, jamming, and data latency will affect data delivery and must be minimized.[128] Additionally, more research is needed for AIT read rates and errors around water, metal, or glass. The most severe limitation of RFID is the read ranges possible. Right now, AIT capabilities are layered (ex. – passive tags, linked to active readers, linked to satellite communications) to account for this; however, the integration and expense are still too high.

- Data Integration: As mentioned previously, RFID systems generate huge volumes of data. The future wireless multi-sensor network will require "making the sensor data available and finding an optimal way to store those data so they can be available for other services and applications."[129] This is further complicated with interoperability requirements with Coalition, commercial, and US government agencies for ongoing IW operations, which requires a shift to security cooperation and whole of government approaches for stability, reconstruction, and transition operations. Each service has legacy, stovepipe systems with fragmented data that may be needed by other systems. The challenge is in integrating the DOD supply chain enterprise and providing the stored data to the customer in need. Most importantly, what system or portal helps commanders manage the deployed inventory and reach back to the enterprise resource system data?
- Software: The architectural framework to fuse legacy systems and new enterprise resource systems is very software and middleware intensive. After the data is captured, learning what to do with all the data becomes a complex software issue as well. The decision-making software will have to be enabled by artificial intelligence systems to recognize patterns or queue the decision maker. Additionally, CAC network access for handheld readers and tag read/write IT systems would require software patches.
- Item-level vs. Container-level Visibility: Tracking shipping containers has limitations, since users remain blind to what is inside the container. The DOD will need the ability to update changes to containers and track those items accurately, or they will be selling short on asset visibility. Odin Technologies demonstrated a "SMART container" in 2009 that uses "passive RFID readers to interrogate tagged items within a container" and then

pass the information to an active tag or satellite communications.[130] This is only a small step in the right direction.

- Design Challenges: As with any system, performance tradeoffs must achieve a balance in the design of AIT. Form factors are dependent on the physics limits on antenna design, power sources, sensing capability, data storage capability, and manufacturing capabilities for mass production. In addition, power will limit the ability to sense the environment for extended periods and be a factor on reuse capabilities. Further, certification of items operating in an RF environment prove challenging (munitions and nuclear material), while certification of items with embedded RFID tags will be a large hurdle. To complicate matters, all these performance characteristics affect the durability and reliability of devices over a life cycle, which challenges requirements for maintenance-free and reusable devices.

SECTION 6: CONCLUSIONS

What are the results and implications of this research considering the challenges? While the challenges are daunting, the benefits of RFID are worthy of further investigation and investment to provide in-transit visibility for DOD's logistics system. While RFID is not the panacea technology for the future, a noteworthy attribute is the flexibility to enhance processes in a myriad of environments. RFID will continue to have a disruptive change to out-dated business process.

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As SSgt Briscoe inspected the HC-130's #3 engine truss mount bolt, he noticed something was not right. The aircrew had reported weird vibrations during today's

mission and the troubleshooting tree pinpointed this area. Black soot hid the cracked bolt head, but not many aircraft discrepancies could get by this keen-eyed Dedicated Crew Chief. As a part of the 71st Expeditionary Rescue Squadron, SSgt Briscoe had adjusted to the sweltering heat and stink of Djibouti. The Horn of Africa was an austere location where progress was being made to oust terrorists trying to find sanctuary in weakly governed African nations. The 71st ERS was there to help. As the sun beat down at 1430 local time, SSgt Briscoe walked over to his toolbox, scanned his ID card over the reader on the side of toolbox, and then picked up his torque wrench with attachments. He really liked the new RFID-tagged tools and the efficiency of the new tool accountability system. With his laptop, he referenced the necessary technical orders, filled out the electronic aircraft forms, and removed the bolt. The process was seamless and quick; however, SSgt Briscoe laughed at how the maintenance actions now took longer than the paperwork. As he inspected the bolt, SSgt Briscoe found the 2-D UID on the bolt and scanned it using the laptop's reader. The UID information combined with the laptop access to the Global Supply Enterprise Network (GSEN) allowed SSgt Briscoe to order parts direct from the flightline. As usual, the bolt was not available on base; however, 13 truss mount bolts were available at the supply warehouse in Ramstein AB. MSgt Perry, the Production Superintendent, came to the aircraft to discuss the situation and verify the part needed ordering MICAP. MSgt Perry scanned his ID card to verify the MICAP. In 20 seconds, the GSEN provided the optimized solution. The bolt would arrive at 2320 tonight on the C-17 rotator. MSgt Perry was pleased and selected the MICAP tracking feature to have auto-updates on the bolt sent directly to his laptop. He could now track the bolt from Ramstein AB to

Djibouti. The currently broke aircraft would make tomorrow's scheduled humanitarian mission to Sudan and allow enough time to reconfigure the aircraft before the bolt arrived. SSgt Briscoe finished the electronic forms, scanned his tools for turn-in, briefed the oncoming shift Crew Chief, and headed to the dining facility. It had been a busy but productive day in the world of aircraft maintenance.

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The scanable ID cards, toolbox auto-checkout, handheld readers to scan old parts, the wireless laptop to view real-time supply levels, the time-definite delivery solution, and the in-transit tracking of the MICAP part – all are enabled by RFID technology. While not possible today, the ability to streamline logistics using networked RFID tags holds great promise. Coupled with the positive trends in enabling technologies, RFID will reshape logistics and facilitate real-time decisions because of complete DOD asset visibility.

Recommendations for an AIT Implementation Roadmap

While USTRANSCOM has an established roadmap and implementation plan contained within the 2007 CONOPS, these recommended inputs are provided as additions in light of this research.

1. The DOD should invest heavily in frequency agile architectures (LF, HF, UHF, VHF, etc.) and network architectures (Wi-Fi, Zigbee, ultra wide band, mesh, ad-hoc, cloud computing, etc.) to capture data in a multi-sensor environment.
2. Develop balanced research strategies to invest in software, software architectures, and middleware that exploit the data available from AIT, enable interoperability with legacy systems, and provide business intelligence for decision-making.

3. The DOD should move decisively to develop a deployable command and control architecture and infrastructure that facilitate real-time decision-making.
4. Ensure information assurance requirements are compliant at all levels of the DOD supply chain with continued exploitation of encryption, anti-counterfeiting, and secure transmission.
5. Evaluate the cost-benefit of RFID implementation according to each unique business process to prevent a cookie-cutter implementation across DOD.
6. Continue investigating and monitoring micro-sensor and satellite linkages to extend the range and functionality of AIT media.
7. Seek opportunities to prototype and integrate new MEMS technology in RFID tags and mobile reader applications.
8. Invest in item-level versus pallet-level visibility where the business process demonstrates a return on investment (ex. – SMART container)
9. Collaborate and incentivize commercial logistics organizations to implement AIT infrastructure and ensure each transportation mode is capable of item-level visibility.
10. Monitor the commercial progress of embedded RFID tags within items and selectively invest R&D resources in those that have direct application to the supply chain.

Research Results

Someone once said, "No matter how much you push the envelope, it'll still be stationery."[131] Advances in AIT have grabbed the attention of scientists, researchers, futurists, governmental officials, the military, and the public. Technology applications have flourished in healthcare, global logistics, manufacturing, nuclear material accountability, maintenance tool

accountability, and intelligence tracking for humans or equipment. In turn, AIT and RFID hold great promise for streamlined supply chains, efficient inventory operations, and situational awareness of assets anywhere.

While micro- and nanotechnologies promise intriguing future capabilities for AIT, technology management and system integration will dictate what is possible over the next two decades. A recent GAO report highlights the imperative for logistics: "lack of visibility over inventory and equipment shipments increases vulnerability to undetected loss or theft and substantially heightens the risk that millions of dollars will be spent unnecessarily."[132] More importantly, an inefficient DOD distribution system will not get critical supplies to combat forces and will impede combat readiness. Now and in the future, it is imperative to sustain forces with the right stuff, delivered to the right place, at exactly the right time. Such an imperative is enabled by a trusted logistics system in the eyes of the customer that saves money, improves performance, and ultimately saves lives. Therefore, the DOD must continue to invest wisely in AIT areas by methodically addressing the infrastructure, hardware, and software capability gaps to exploit the capabilities of logistics situational awareness in the coming decades. In the networked battlespace of 2035, the U.S. must have the ability to provide end-to-end visibility throughout the DOD supply chain and enable real-time decision-making by commanders. AIT, specifically RFID, will be the lynchpin of DOD operations to ensure U.S. forces can rapidly mobilize, deploy, sustain, and re-deploy in support of national security objectives.

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APPENDIX A: EXPERT CONTACT INFORMATION

United States Transportation Command (USTRANSCOM)
http://www.transcom.mil/ait/
http://www.acq.osd.mil/log/rfid/index.htm
Contact: OM Asset Visibility Division TCJ5/4-I
Strategy, Policy, Programs, and Logistics/TCJ5/4
US Transportation Command, Scott AFB IL 62225
618-229-1130/DSN 779-1130
USTCJ5J4-I@ustranscom.mil
Focus: Command lead for USTRANSCOM'S responsibilities as DOD lead functional proponent for Radio Frequency Identification (RFID) and related Automatic Identification Technology (AIT) implementation for the DOD supply chain; Command focal point for DOD lead responsibilities for RFID and AIT standards, security, and technical matters; participates in DOD, commercial, national, and international standards committees and forums.

Defense Logistics Agency (DLA)
http://www.dla.mil/
Focus: DOD Suppliers, Parts, and Contracts

AF AIT Program Office
https://afkm.wpafb.af.mil/ASPs/CoP/OpenCoP.asp?Filter=OO-LG-AI-T2
POC: Mark Reboulet, AIT Program Manager
Contact: 937-257-7181
Focus: AF AIT Technology investment

AF Logistics Management Agency (AFLMA)
http://www.aflma.hq.af.mil/
Focus: AF Logistics Applications and Requirements

Army AIT Program Office
http://www.eis.army.mil/ait/
Contact: PM J-AIT
Attn: SFAE-PS-AIT
8580 Cinder Bed Road, Suite 1400
Newington, VA 22122
Telephone: (703) 339-4400 x107 and x103
Fax: (703) 339-4401
Focus: PM J-AIT manages the Government AIT contracts; Army AIT technology investment

"Each of the Services and USTRANSCOM as the DoD proponent, maintain AIT offices. PM J-AIT is an Army agency serving as the acquisition and technology proponent for AIT and is responsible for representing DOD interests in AIT related technical committees of national and international standards bodies. We also support demonstrations aimed at expanding the use of other AIT logistics functions, particularly those key to effective deployments, which ensure compatibility of devices, codes, and equipment, and provide the DOD and other selected non-

DoD agencies with centralized product procurement and management services to support AIT. As such, PM J-AIT is the focal point for new technology insertion and integration into existing information systems and tactical logistics systems.

The DoD AIT office manages the DoD Logistics AIT effort. They are the functional proponent for AIT and have functional responsibility to coordinate logistics AIT research and applications with other functional areas. Additionally, they participate in private sector AIT user groups to improve commercial and military logistics interoperability and advocate process improvement through the use of AIT, and approve AIT applications. As part of that responsibility, they oversee the DoD Logistics AIT program as directed by the DoD Logistics AIT Concept of Operations (CONOPS) and DoD Logistics AIT Implementation Plan

The designated AIT program offices that represent the various services and the US Coast Guard are primarily responsible for identifying opportunities for AIT insertion for their specific needs and ensuring that service AIT policies and standards are met." (Sourced from http://www.eis.army.mil/ait/)

PM J-AIT Acquisition and Testing Laboratory
POC: John Domin
Contact: john.domin@us.army.mil, (570) 615-7875/7951/6404 (DSN 795)
Focus: Technical requirements for inclusion into AIT RFPs; Monitor the AIT industry to identify new or emerging technologies for potential inclusion into the PM J-AIT contracts; Provide directed support to all DOD services with respect to all types of AIT initiatives, equipment issues, functional AIT equipment operation, program development, prototype support, and equipment troubleshooting.

Center for Army Lessons Learned (CALL)
http://usacac.army.mil/cac2/call/index.asp
Focus: Applicable lessons learned with AIT

Federal Express (FED-X)
http://www.fedex.com/us/electronics/industrynews/trends.html
Focus: Current commercial application and future investment

Transcore Inc.
http://www.transcore.com/
Focus: Commercial supplier

Wal-Mart
http://walmartstores.com/FactsNews/FactSheets/
Focus: Current commercial application and future investment

University of Arkansas RFID Research Center
http://itri.uark.edu/rfid.asp
POC: Dr. Bill Hardgrave
Contact: bhardgrave@walton.uark.edu , 479-575-6099
Focus: Academic research, applications, and future investment

University of Dayton
http://www.udayton.edu
POC: Dr. Patrick J. Sweeney, Interim Chairperson
Contact: Department of Engineering Management and Management Science
University of Dayton
300 College Park
Dayton, OH 45469-0236
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937-229-2238
Focus: Academic research, applications, and future investment

Odin Technologies
http://www.odintechnologies.com
POC: Patrick J. Sweeney II, CEO
Focus: State of the art applications and future investment

MIT Auto-ID Laboratory
http://Autoid.mit.edu
POC: Sanjay Sarma
Focus: Academic research, applications, and future investment

DOD Unique Item Identification
www.acq.osd.mil/dpap/UID/
POC: Darrell Nitz
Contact: UID/SNT OPR Hill AFB, 801-586-2153 (DSN 586)
Focus: Implementation, packaging applications, and future investment

Layered Security
POC: Bryce Galbraith
Contact: bryce@layeredsec.com
Focus: Networks, security, and privacy concerns

APPENDIX B: QUESTIONS FOR EXPERTS

As the research proceeded, contacting experts proved to be more difficult and time consuming than originally planned. Particularly, industry was hesitant to talk about future investments in technology due to competitive advantage concerns. Additionally, government contacts in USTRANSCOM never responded to information requests. In response, a more thorough literature review and internet search was conducted to examine the industry and government policies, technology developments, and future plans. In light of the low response, two very helpful expert contacts provide supplementary information about industry and government investments. First, Dr. Bill Hardgrave, RFID Research Center Director at the University of Arkansas, provided a wealth of information on Wal-Mart, Federal Express, and the DOD. Dr. Hardgrave's background in information technology and contacts with government and industry proved vital to this research. Secondly, Mark Reboulet, USAF AIT Program Manager, and his staff provided a solid understanding of USTRANSCOM's vision for RFID and shared the AF investment plans for AIT. Collectively, Dr. Hardgrave and Mr. Reboulet were the perfect resources for this research and more than made up for the lack of response from the other agencies and experts.

The following information is provided to detail the questions asked to the experts.

Date/Time: 10 March 2010
Interview Type (In Person, Email, Phone, Video Teleconference, Blog): Phone
Participant: Dr. Bill Hardgrave, Executive Director, Information Technology Research Institute/RFID Research Center, University of Arkansas
Participant Contact: bhardgrave@walton.uark.edu , 479-575-6099
Questions:

1. INTRO
2. How long have you been Director of the RFID Research Center?
3. Hype cycle: What is the reason for the breakthrough in 2008 for going up the slope of enlightenment?
4. What is the most promising benefit?
5. What do you mean by people management?

6. What do you mean by form factor as a limitation?
7. What do you see as the biggest challenge?
8. Vision of RFID technology?
9. Investment for vision?
10. Bandwidth and interference issues in multi-sensory environment?

Date/Time: 24 February 2010
Interview Type (In Person, Email, Phone, Video Teleconference, Blog): Email
Participant: Dr. Bill Hardgrave, Executive Director, Information Technology Research Institute/RFID Research Center, University of Arkansas
Participant Contact: bhardgrave@walton.uark.edu , 479-575-6099
Questions:

1. In one of your 2006 research papers, you identified the myths and realities of RFID technologies. Where on the hype cycle would you rate RFID?
2. What are the most promising benefits and applications you see with current RFID technology?
3. In October 2009, ITRI held an item-level RFID event where one of the conclusions was "greater RFID benefits can be derived from item-level tagging." Is the leap in benefit from pallet-level to item-level tagging worth the investment/effort? Why?
4. What do you see as the biggest challenges or limitations with current RFID technology?
5. What considerations need to be planned for when networking RFID-tagged items?
6. In all the research done to date, data security and privacy seem to be contentious issues. What security and privacy concerns should be addressed before implementing an RFID system?
7. Looking into the crystal ball, do you have a vision for what a RFID network/system would look like in 2035? What is it?
8. How is this vision different from what is capable today? Specifically, where are the capability gaps?
9. In the 2009 ITRI "Top IT Issues," the economy affected every issue in some way. In light of this, what enabling technologies are industry and academia investing in **now** to make the 2035 vision a reality? What are the general priorities?
10. What additional enabling technologies **should be** invested in to make the 2035 vision a reality?
11. I have focused specifically on RFID for my paper to limit the scope. However, are there other IT developments/trends (infrastructure, organization, policy, interoperability with legacy systems, software, miniaturization, etc.) that you would recommend I include in my paper?
12. Are there additional resources or people that you would recommend I pursue to help with this research?

Date/Time: 3 March 2010 (email), 12 March 2010 (phone)
Interview Type (In Person, Email, Phone, Video Teleconference, Blog): Email/Phone
Participant: Mark Reboulet, AF AIT Program Manager, 403 SCMS/GUEA
Participant Contact: mark.reboulet@wpafb.af.mil , 937-257-7181
Questions:

1. With a lot of current interest in RFID technologies, myths and realities abound. Where on the hype cycle would you rate RFID?
2. What are the most promising benefits and applications you see with current RFID technology?
3. What do you see as the biggest challenges or limitations with current RFID technology?
4. In all the research done to date, data security and privacy seem to be contentious issues. What security and privacy concerns should be addressed before implementing an RFID/AIT system?
5. In March 2009, there was an AIT Warfighter Conference where government and industry presented the "state of AIT." One of the issues is aligning AIT initiatives with leading commercial business practices. How is the AF doing this?
6. Does the AF have an AIT or RFID implementation roadmap? If so, who owns/controls it?
7. Looking into the crystal ball, do you have a vision for what a RFID network/system would look like in 2035? What is it?
8. How is this vision different from what is capable today? Specifically, where are the capability gaps?
9. What enabling technologies is the AF investing in **now** to make the 2035 vision a reality? What are the general priorities?
10. Without budget constraints, what additional enabling technologies **should be** invested in to make the 2035 vision a reality?
11. I have focused specifically on RFID for my paper to limit the scope. However, are there other AIT developments/trends (infrastructure, organization, policy, interoperability with legacy systems, software, miniaturization, etc.) that you would recommend I include in my paper? Why?
12. Are there additional resources or people that you would recommend I pursue to help with this research?

Date/Time: 8 March 2010
Interview Type (In Person, Email, Phone, Video Teleconference, Blog): Email
Participant: John Domin, Army PM J-AIT Acquisition and Testing Laboratory
Participant Contact: john.domin@us.army.mil , DSN 795-7875
Questions:

1. With a lot of current interest in RFID technologies, myths and realities abound. Where on the hype cycle would you rate RFID?
2. As the Army Laboratory for AIT implementation, how successful has the Army been in implementing these technologies throughout the Army supply chain?
3. What are the most promising benefits and applications you see with current RFID/AIT technology?
4. What do you see as the biggest challenges or limitations with current RFID technology?
5. In all the research done to date, data security and privacy seem to be contentious issues. What security and privacy concerns is the Army currently working on to address RFID/AIT implementation?
6. One issue highlighted in recent AIT conferences is aligning AIT initiatives with leading commercial business practices. How is Army doing this?
7. How does the UID program tie into the vision for RFID in the DOD?

8. Does the Army have an AIT or RFID implementation roadmap? If so, who owns/controls it?
9. Looking into the crystal ball, do you have a vision for what a RFID network/system would look like in 2035? What is it?
10. How is this vision different from what is capable today? Specifically, where are the capability gaps?
11. The Army Laboratory monitors the AIT industry to identify new or emerging technologies for potential inclusion into the PM J-AIT contract vehicles. What enabling technologies is the Army investing in **now** to make the 2035 vision a reality? What are the general priorities in the Army? How is this synchronized between the services?
12. Without budget constraints, what additional enabling technologies **should be** invested in to make the 2035 vision a reality?
13. I have focused specifically on RFID for my paper to limit the scope. However, are there other AIT developments/trends (infrastructure, organization, policy, interoperability with legacy systems, software, miniaturization, etc.) that you would recommend I include in my paper? Why?
14. Are there additional resources or people that you would recommend I pursue to help with this research?

Date/Time: 2 March 2010
Interview Type (In Person, Email, Phone, Video Teleconference, Blog): Email
Participant: TBD, USTRANSCOM
Participant Contact: Email? , 618-229-1130/DSN 779-1130
OM Asset Visibility Division TCJ5/4-I
Strategy, Policy, Programs, and Logistics/TCJ5/4
US Transportation Command, Scott AFB IL 62225
Questions:

1. With a lot of current interest in RFID technologies, myths and realities abound. Where on the hype cycle would you rate RFID?
2. As the DOD lead functional proponent for RFID and AIT implementation, how successful has the DOD been in implementing these technologies throughout the DOD supply chain?
3. What are the most promising benefits and applications you see with current RFID/AIT technology?
4. What do you see as the biggest challenges or limitations with current RFID technology?
5. In all the research done to date, data security and privacy seem to be contentious issues. What security and privacy concerns is the DOD currently working on to address RFID/AIT implementation?
6. One issue highlighted in recent AIT conferences is aligning AIT initiatives with leading commercial business practices. How is USTRANSCOM doing this?
7. The 11 Jun 2007 AIT CONOPS has an intended horizon of FY2010–2015 and provides a vision for AIT. When is the next update expected to keep pace with technology advancements?
8. How does the UID program tie into the vision for RFID in the DOD?
9. Looking into the crystal ball, do you have a vision for what a RFID network/system would look like in 2035? What is it?

10. How is this vision different from what is capable today? Specifically, where are the capability gaps?
11. What enabling technologies is the DOD investing in **now** to make the 2035 vision a reality? What are the general priorities in the DOD? How is this synchronized between the services?
12. Without budget constraints, what additional enabling technologies **should be** invested in to make the 2035 vision a reality?
13. I have focused specifically on RFID for my paper to limit the scope. However, are there other AIT developments/trends (infrastructure, organization, policy, interoperability with legacy systems, software, miniaturization, etc.) that you would recommend I include in my paper? Why?
14. Are there additional resources or people that you would recommend I pursue to help with this research?

Date/Time: 23 February 2010
Interview Type (In Person, Email, Phone, Video Teleconference, Blog): Email
Participant: Bryce Galbraith, Layered Security
Participant Contact: bryce@layeredsec.com
Questions:

1. What benefits and applications do you see with current RFID technology?
2. What do you see as the biggest challenges or limitations with current RFID technology?
3. What considerations need to be planned for when networking RFID-tagged items?
4. What security and privacy concerns should be addressed before implementation?
5. Do you have a vision for what a RFID network would look like in 2035? What is it?
6. How is this vision different from what is capable today? Capability gaps?
7. What enabling technologies should be invested in now to make your 2035 vision a reality?
8. Are there additional resources or people that you would recommend I pursue to help with this research?

APPENDIX C: RFID APPLICATIONS

(Sourced from http://www.eis.army.mil/ait/technology/faqs.asp)

- ISO container tracking
- Vehicle tracking
- Fleet management
- Deployment support
- Air pallet tracking and accountability
- Repair parts tracking
- Warehouse management and inventory
- Manufacturing production control
- Sensitive items inventory/issue
- Reusable container tracking
- Ammunition tracking, receipt, and inventory
- Supply chain management
- Cargo security
- Cargo classification
- Reparable parts tracking and financial credit verification
- Personnel locating
- Personnel access control
- Baggage tracking
- Marathon runner tracking/timing
- Library book inventory/sign-out
- Retain anti-theft
- Industrial clothing cleaning plant control
- Biometrics validation
- MHE tracking
- Medical equipment locating
- Tracking criminals
- Tracking livestock
- Pharmaceutical accountability/safety
- Passports
- Credit Cards
- Toll collection

APPENDIX D: RESEARCH NOTES

Nuclear Enterprise

- Accountability
- Inventory/tracking of material/parts
- Non-proliferation and Treaty inspections
- Shielding/EMI issues
- Security/Integrity/Encryption
- Taiwan Shipment Fact Sheet
  http://www.defense.gov/DODCMSShare/briefingslide/332/080605-D-6570C-001.jpg
- Transcript of Secretary Gates Speech: Nuclear Revitalization
  http://www.defense.gov/transcripts/transcript.aspx?transcriptid=4236

Questions for Industry/Commercial

1. How does your company currently use AIT or RFID? What applications?
2. How was RFID implemented?
3. What benefits do you see with current RFID technology?
4. How has RFID changed the way you conduct business?
5. What do you see as the biggest challenges or limitations with current RFID technology?
6. How are you currently addressing these challenges or limitations?
7. Do you currently operate a RFID network within your company?
8. What considerations need to be planned for when networking RFID-tagged items?
9. Do you feel standardized policies and procedures are robust for RFID?
10. What security and privacy concerns should be addressed before implementation?
11. Are you currently pursuing future RFID technologies, policies, or procedures?
12. What enabling RFID technologies are you pursuing?
13. If you could look in the crystal ball to 2035, how does RFID fit into your business vision?
14. What capabilities does RFID bring your company in 2035?
15. How is this vision different from what is capable today?
16. What capability gaps exist today that are hindering you from achieving this vision?
17. What enabling technologies should be invested in now to make your 2035 vision a reality?
18. Are there additional resources or people that you would recommend I pursue to help with this research?

Questions for Academia

1. What benefits and applications do you see with current RFID technology?
2. What do you see as the biggest challenges or limitations with current RFID technology?
3. What considerations need to be planned for when networking RFID-tagged items?
4. What security and privacy concerns should be addressed?
5. Do you feel standardized policies and procedures are robust for RFID? If not, what issues exist?
6. Do you have a vision for what a RFID network would look like in 2035? What is it?
7. How is this vision different from what is capable today?
8. What capability gaps exist?
9. What technology trends do you see that would enable advances in RFID?

10. What enabling technologies should be invested in now to make your 2035 vision a reality?
11. What recommend strategy would you use to prioritize technology development for RFID?
12. Are there additional resources or people that you would recommend I pursue to help with this research?

Questions for Government

1. How does the DOD currently use AIT/RFID?
2. What benefits and applications do you see with current RFID technology?
3. Do you feel the DOD has been successful in fully implementing RFID technology?
4. What do you see as the biggest challenges or limitations with current RFID technology?
5. How is the DOD addressing these challenges and limitations?
6. Is there a current or future requirement to network RFID-tagged items?
7. What considerations need to be planned for when networking RFID-tagged items?
8. What security and privacy concerns should be addressed?
9. Do you feel commercial/DOD standardized policies and procedures are robust for RFID? If not, what issues exist?
10. Do you have a vision for how the DOD can apply RFID technology in 2035? What is it?
11. How is this vision different from what is capable today?
12. What capability gaps exist?
13. What technology trends do you see that would enable advances in RFID?
14. What enabling technologies should be invested in now to make your 2035 vision a reality?
15. What recommend strategy would you use to prioritize technology development for RFID?
16. Are there additional resources or people that you would recommend I pursue to help with this research?